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CONTROL OF THE INERTIA WHEEL PENDULUM TAKING INTO ACCOUNT THE ACTUATOR DYNAMICS

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Abstract. *In this work, we propose a control scheme to swing up and balance the inertia wheel pendulum. This is done by combining two controllers: a trajectory tracking controller solves the swinging up task whereas a linear controller balances the pendulum at the unstable configuration. The main contribution of this note is that, for the first time, both of these controllers are designed taking into account the electric dynamics of the brushed DC-motor used as actuator. This is important to ensure that any instability is not produced by the electric dynamics.*
Keywords: Actuator dynamics, Asymptotic stability, Inertia wheel pendulum, Underactuated mechanical systems

1. **Introduction.** The inertia wheel pendulum (IWP) was introduced in [1] as a benchmark for advanced nonlinear control and academic purposes. The IWP is a two degrees of freedom underactuated mechanical system, composed by a planar pendulum with a revolving wheel placed at the end (see Figure 1). The pendulum and the wheel axes are parallel. The pendulum joint is unactuated whereas the wheel joint is actuated [2, 3].

A common strategy to swing up and balance the IWP involves switching between two controllers. This control scheme was presented in [1, 3] where an energy-based nonlinear controller is designed to swing up the IWP and a linear controller catches the pendulum at the unstable configuration. Although some controllers were introduced in [2, 4] solving the entire task without switching (i.e., using a single controller to swing up and balance the IWP), a large torque input is demanded and it is not clear whether these control strategies can be made to work on the actual physical system. This observation was also remarked in [1].

The interconnection and damping assignment passivity-based control (IDA-PBC) approach presented in [4], which was intended for Hamiltonian systems, was extended for the IWP from a Lagrangian point of view in [5]. This was done by using Lyapunov stability and the LaSalle's invariance principle. These results were further extended in [6] to the case when the applied torque has to remain within prescribed limits. Another controller designed by assuming saturated torques was presented recently in [7].

Some other works have been devoted to friction modeling and parameter identification for the IWP [8, 9]. Further, a feedback linearization controller which takes into account the viscous friction was presented in [10]. This controller, however, only solves the balancing problem.

A surface control technique was presented in [11, 12] to swing up and balance the IWP achieving exponential stabilization results.